SOUNDCAST CALIBRATION AND SENSITIVITY TEST RESULTS (DRAFT)

Puget Sound Regional Council

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This document describes the activity-based model calibration to the 2010 using the following observed data sources: the 2006 household travel survey, 2010 observed highway counts, 2010 transit boardings, 2010 CTPP, and 2010 ACS numbers. The document also shows the results of applying the model in various scenarios to understand its sensitivities. The document begins with a review of the system design for reference and ends with recommendations for model improvements based on the sensitivity tests and calibration results.

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INTRODUCTION AND MODEL SYSTEM OVERVIEW

SoundCast is a travel demand model system built for the Puget Sound Region, as shown in Figure 1. SoundCast model design. The model was built to depict diverse human travel behavior and include travel sensitivity to land use and the built environment. SoundCast outputs transportation network measures such as highway volumes in one hour periods in a future year or number of boardings on a transit line. It also outputs measures related to people like average distance to work by home county or the number of transit trips different types of people will take.

The three main components of SoundCast are:

- person trip demand in the **Daysim** activity-based model
- external, special generation, truck, and group quarters aggregate modeling
- assignment and skimming in **EMME**

DaySim is a modeling approach and software platform to ***simulate resident daily travel*** and activities on a typical weekday for the residents of a metropolitan region or state.

In essence, DaySim replaces the trip generation, trip distribution and mode choice steps of a 4-step model, while ***representing more aspects of travel behavior*** *(auto ownership, trip chaining, time of day scheduling, detailed market segmentation, etc.)*

Daysim ***integrates with EMME*** by generating resident trip matrices for assignment and uses the network skims from assignment for the next global iteration of DaySim.

The major inputs to SoundCast are transportation networks and modeled household and employment data from UrbanSim. In Daysim, The Population Synthesizer (PopSyn) creates a synthetic population, comprised of Census PUMS households, that is consistent with regional residential, employment and school enrollment forecasts. Long-term choices (work location, school location and auto ownership) are simulated for all members of the population. The Person Day Activity and Travel Simulator (DaySim) creates a one-day activity and travel schedule for each person in the population, including a list of their tours and the trips on each tour.

The trips predicted by DaySim are aggregated into EMME trip matrices and combined with predicted trips for special generators, external trips and commercial traffic into time- and mode-specific trip matrices. The EMME network traffic assignment models load the trips onto the network. Traffic assignment is iteratively equilibrated with the Long Term Choice Simulator, DaySim and the other demand models. The parcel level land use inputs come from UrbanSim.

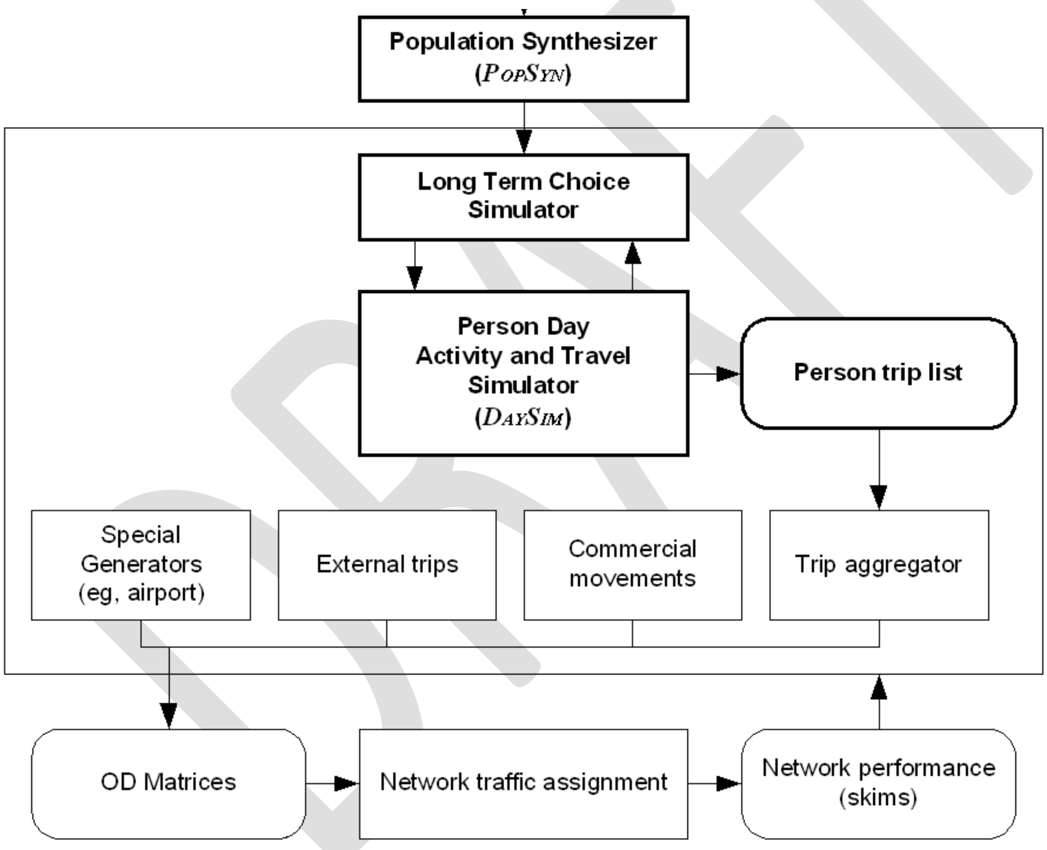

Figure 1. SoundCast model design

The sub-models in the DaySim system are:

1. Work Location
2. School Location

3. Pay to Park at Work
4. Transit Pass Ownership
5. Auto Ownership
6. Individual Person Day Pattern
7. Exact Number of Tours
8. Work Tour Destination
9. Other Tour Destination
10. Work-based subtour Generation
11. Work Tour Mode
12. Work Tour Time
13. School Tour Mode
14. School Tour Time
15. Escort Tour Mode
16. Escort Tour Time
17. Other Tour Mode
18. Other Tour Time
19. Work-Based Subtour Mode
20. Work-Based Subtour Time
21. Intermediate Stop Generation
22. Intermediate Stop Location
23. Trip Mode
24. Trip Time

Calibration Results

Individual model components have been calibrated to loosely match the 2006 household survey, the 2010 CTPP, 2010 Highway Counts, 2006-2010 ACS, and 2010 boarding data. Since we are attempting to match multiple targets, that can be conflicting at the same time, we cannot always match target calibration numbers. Also we need to ensure that the model still has enough sensitivity to show the impact of alternative policies, so we often sacrifice matching a target exactly for model sensitivity to a variable.

For example, you could exactly match transit mode share to work against the survey, but that may not match the observed boardings data due to discrepancies between the data sources. Also, you can easily over-calibrate the constant so that the model is no longer sensitivity to important variables like the level of service.

In this document, the model results will be compared to the observed data for each model component. Then the overall assignment results are shown.

Although SoundCast is an activity-based model with detailed person and accessibility variables, it still predicts the number of trips and trip lengths in the end like a trip-based model. Table 1 shows the overall results comparing SoundCast to the 2006 GPS-weighted household travel survey.

Table 1. Average Number of Trips and Length of Trips

Total Trips				
	SoundCast 2010	**2006 Survey (GPS Weighted)**	**Difference**	**% Difference**
Average Trips Per Person	4.18	4.24	-0.06	-1.38%
Average Trip Length	6.15	6.06	0.09	1.44%

Long Term Choices

Work Location

The work location model predicts which work parcel a worker usually works at. One of the options in the model is to work at home. Table 2 shows the percent of workers who work at home in the model compared to the CTPP; Table 3 shows the number of workers at home by home geography. It appears the model is slightly under-predicting working at home in King County and over-predicting working at home in the counties. The work at home alternative only includes a few variables. Because we are not accurately capturing the breakdown by home county, we should consider adding variables that might capture this behavior like income, household size, or accessibility.

Table 2. Percent of Workers at Home

	SoundCast 2010	**2006-2010 CTPP**
Total Workers at Home	97421	91615
Total Workers	1786311	1805125
Share at Home (%)	5.5%	5.1%

Table 3. Number of Workers at Home by Home Geography

Home County	SoundCast 2010	2006-2010 CTPP
King	42049	53625
Kitsap	13350	6475
Pierce	23435	15705
Snohomish	18587	15810

One way to verify if the work location model is predicting realistic work parcels is by looking at the average distance to work, as shown in Table 4 and

Figure 2.

This table indicates a potential over-calibration of the average distance to work. The targets are met so precisely that the model is most likely losing sensitivity to other variables that impact work location choice like travel time. The model does appear sensitive, however, to age and person type.

Table 4. Average Distance to Work by Person Group

	Average Distance to Work			
	SoundCast 2010	Survey 2006	Difference	% Difference
Total	12.3	12.4	0.0	-0.3%
Full-Time	13.7	13.3	0.3	2.4%
Part-Time	8.5	8.4	0.1	0.9%
Female	10.6	10.8	-0.1	-1.3%
Male	13.8	13.9	-0.1	-0.6%
Age Under 30	10.5	10.8	-0.3	-3.1%
Age 30-49	13.0	13.0	0.0	0.1%
Age 50-64	13.1	12.5	0.6	4.5%
Age Over 65	10.8	10.7	0.2	1.6%

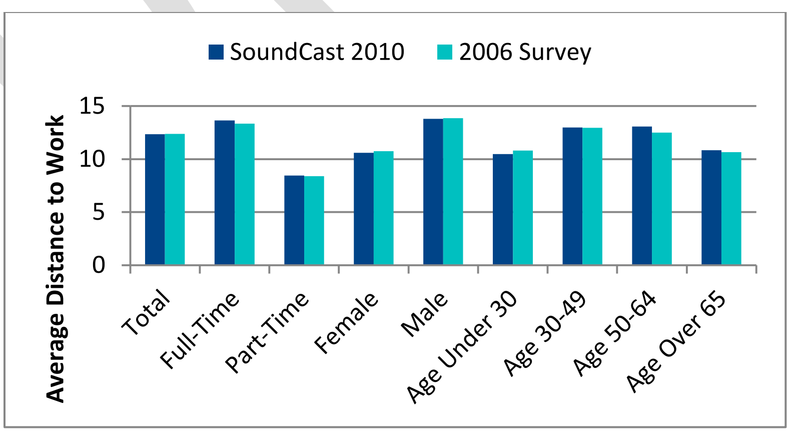

Figure 2. Average Distance to Work by Person Type

Another way work location models are calibrated is by looking by the flows from home district to work district. Figure 3 shows the planning districts we use for this summary.   The targets for the home-to-work flows were derived from the 2010 CTPP and are shown in Table 5. An iterative proportional fitting(ipf) was performed to develop the target. The 2010 CTPP was used as a seed matrix, with the employment by district as the row sum, and the workers by district as the column sum, in this ipf. The SoundCast home to work flow is shown in Table 6. Comparing the two tables indicates some areas of concern in this calibration that could be fixed with more district to district constant calibration or better variable selection.

- Too many workers who live in Everett-Lynnwood-Edmonds are staying in district to work.
- Not enough East Side workers are going to the CBD to work, too many are staying on the East Side.
- Not enough South Pierce Workers are going to Tacoma.
- Too many West-South Seattle Workers are staying in West-South Seattle

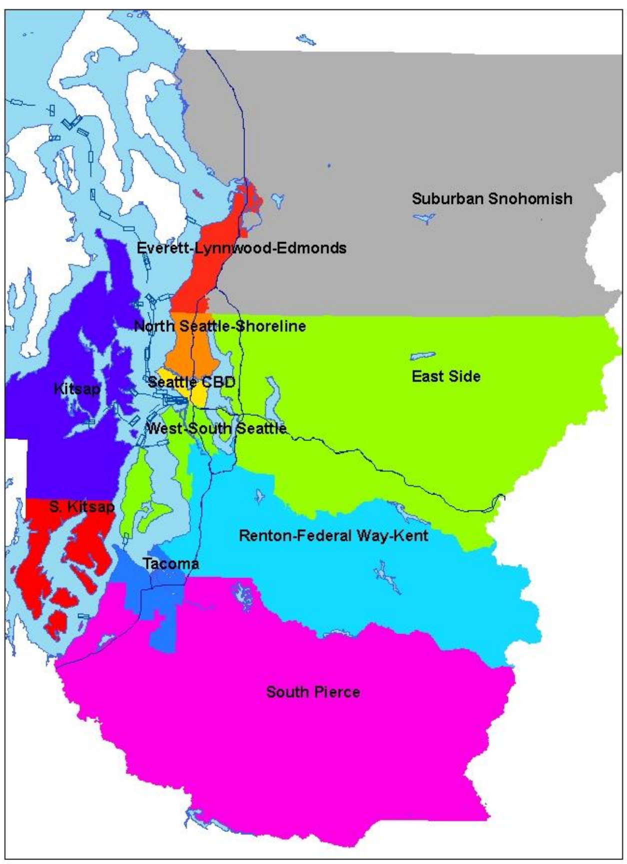

Figure 3. SoundCast Planning Districts

Table 5. Home District-Work District calibration targets based on 2010 CTPP

	Work District										
Residence District	**Suburban Snohomish**	**Everett-Lynwood-Edmonds**	**North Seattle-Shoreline**	**Seattle CBD**	**West-South Seattle**	**East Side**	**Renton-FedWay-Kent**	**Tacoma**	**Kitsap + S. Kitsap**	**South Pierce**	**Grand Total**
Suburban Snohomish	76,946	64,233	8,666	10,548	12,082	25,750	5,043	408	518	425	210,487
Everett-Lynwood-Edmonds	21,867	61,484	12,060	13,864	8,756	15,838	3,739	281	357	323	131,999
North Seattle-Shoreline	3,012	8,515	64,779	49,754	14,067	19,389	8,309	847	416	490	172,217
Seattle CBD	892	1,443	13,503	56,388	7,243	15,622	5,954	768	251	182	101,543
West-South Seattle	2,868	4,464	12,351	26,149	27,871	27,637	12,936	716	193	403	116,262
East Side	5,887	5,422	12,174	39,188	18,207	231,788	28,994	1,283	551	781	310,414
Renton-FedWay-Kent	1,827	1,775	11,056	30,340	21,953	34,779	149,467	8,803	691	7,717	272,558
Tacoma	182	123	1,531	3,404	2,024	2,618	18,141	55,880	775	24,354	106,948
Kitsap + S. Kitsap	298	1,294	1,183	6,723	1,857	1,615	1,875	2,492	111,750	3,346	123,636
South Pierce	458	570	2,117	5,526	3,837	4,789	34,366	51,736	3,051	89,744	219,726
Grand Total	105,325	152,639	140,420	246,772	129,373	331,261	287,824	120,121	108,153	143,903	1,765,791

Table 6. SoundCast Home District-Work District Results

	Work District										
Residence District	**Suburban Snohomish**	**Everett-Lynwood-Edmonds**	**North Seattle-Shoreline**	**Seattle CBD**	**West-South Seattle**	**East Side**	**Renton-FedWay-Kent**	**Tacoma**	**Kitsap + S. Kitsap**	**South Pierce**	**Grand Total**
Suburban Snohomish	81,123	45,763	17,089	22,671	8,002	25,703	8,805	727	75	655	210,613
Everett-Lynwood-Edmonds	9,417	83,655	10,820	11,837	4,418	7,497	3,699	349	87	299	132,078
North Seattle-Shoreline	4,694	9,703	64,459	53,024	14,823	14,135	9,817	816	96	753	172,320
Seattle CBD	973	1,876	13,840	57,917	13,493	6,151	6,348	508	65	433	101,604
West-South Seattle	960	1,787	8,386	34,442	39,572	2,849	24,613	2,078	60	1,584	116,331
East Side	4,704	4,488	9,137	20,104	8,655	245,083	16,264	1,095	38	1,032	310,600
Renton-FedWay-Kent	1,935	2,611	9,591	30,581	25,022	19,321	153,250	15,058	326	15,026	272,721
Tacoma	347	497	1,705	5,117	4,350	2,614	18,349	50,847	2	23,184	107,012
Kitsap + S. Kitsap	521	1,278	1,851	89	2,486	1,369	2,577	4,337	106,445	2,757	123,710
South Pierce	714	1,072	3,626	11,137	8,629	6,737	44,274	44,378	1,024	98,266	219,857
Grand Total	105,388	152,730	140,504	246,919	129,450	331,459	287,996	120,193	108,218	143,989	1,766,846

School Location

Table 7 and Figure 4. Average Distance to School by Age show that the school location choice models are producing results similar to the survey for average distance to school by age group.

Table 7. Average Distance to School by Age

Average Distance to School				
	DaysimOutputs	**Survey**	**Difference**	**% Difference**
All	5.3	5.3	0.0	-0.7%
Under 5	4.5	5.2	-0.7	-12.6%
5 to 12	3.8	4.1	-0.3	-7.3%
13 to 18	4.5	4.4	0.0	1.0%
Over 19	9.3	10.8	-1.5	-14.2%

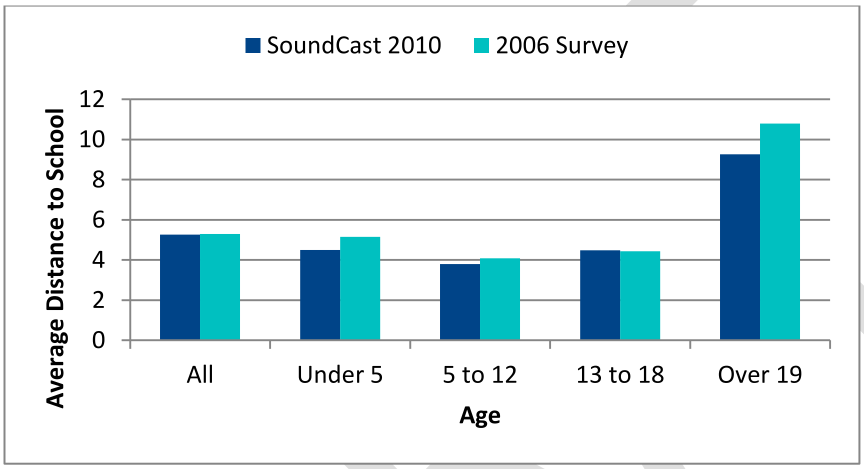

Figure 4. Average Distance to School by Age

Vehicle Ownership

Table 8, Table 9, and Table 10 show the results from the vehicle ownership model compared to the 5 year Census Transportation Planning Package (CTPP). The model is matching CTPP well. The model is sensitive to geographic factors and income, since we can see that shares by county and income are variable.

Table 8. Percent of Households by Number of Household Vehicles

Number of Vehicles in Household	% of Households (SoundCast 2010)	% of Households (2006-2010 CTPP)	Difference	% Difference
0	7.6%	7.4%	0.2%	3.1%
1	29.1%	32.2%	-3.2%	-9.9%
2	38.9%	37.4%	1.5%	4.1%
3	16.5%	15.4%	1.1%	6.9%
4+	7.9%	7.5%	0.4%	5.3%

Table 9. Percent of Households by Home County by Household Vehicles

County	0 Cars (SoundCast) (%)	0 Cars (CTPP) (%)	1 Car (SoundCast) (%)	1 Car (CTPP) (%)	2 Cars (SoundCast) (%)	2 Cars (CTPP) (%)	3 Cars (SoundCast) (%)	3 Cars (CTPP) (%)	4+ Cars (SoundCast) (%)	4+ Cars (2006-2010 CTPP) (%)
King	9.7%	9.5%	29.9%	34.6%	37.3%	36.5%	15.7%	13.7%	7.4%	5.8%
Kitsap	4%	3.1%	28.2%	31.4%	42.2%	37.5%	17.2%	17%	8.4%	11%
Pierce	6.3%	5.6%	28.6%	30.4%	39.6%	38.8%	17.1%	16.8%	8.4%	8.4%
Snohomish	4.2%	4.9%	27.4%	27.8%	41.7%	38.4%	17.9%	18.5%	8.8%	10.5%

Table 10. Percent of Households by Income by Vehicle Ownership

Household Income	0 Cars (SoundCast) (%)	0 Cars (CTPP) (%)	1 Car (SoundCast) (%)	1 Car (CTPP) (%)	2 Cars (SoundCast) (%)	2 Cars (CTPP) (%)	3 Cars (SoundCast) (%)	3 Cars (CTPP) (%)	4+ Cars (SoundCast) (%)	4+ Cars (CTPP) (%)
Less than $20,000	33.5%	36.1%	44.4%	50.7%	15.5%	10.2%	5.0%	2.0%	1.6%	1.1%
$20,000-$39,999	10.9%	11.5%	48.7%	55.5%	28.1%	23.7%	9.3%	6.3%	3.1%	2.9%
$40,000-$59,999	5.4%	2.5%	38.7%	37.5%	36.8%	39.1%	13.7%	16.3%	5.4%	4.6%
$60,000-$74,999	1.7%	1.6%	25.0%	25.3%	45.3%	47.8%	19.2%	16.7%	8.9%	8.6%
More than $75,000	0.3%	0.3%	11.8%	11.4%	50.7%	50.5%	24.1%	24.9%	13.1%	12.8%

Transit Pass Ownership

SoundCast predicts whether a person will own a transit pass or not. This then later impacts transit fare cost in the decision to use transit. The model is predicting a little more transit pass ownership than was observed.

	SoundCast 2010	2006 Survey
Total Transit Passes	522600	348575
Transit Passes per Person	0.15	0.11

Day Pattern Choices/Tour and Trip Generation

During travel model calibration, modelers often find that to match observed road counts and transit boardings in assignment, the number of trips and tours must be increased from what was observed in the survey. In other words, the household travel survey and the road counts show different amounts of travel activity. This has been shown to be because of underreporting of trips by about 20% in the household travel survey because of survey fatigue. Furthermore, certain types of trips like non-work and non-school trips are underreported more than mandatory trips. Because of this, we increase the number of trips and tours for non-mandatory purposes like social and personal business to account for underreporting. The slight intentional discrepancy between the survey and the model can be seen the following tables.

Table 11. Average Tours per Person

	SoundCast 2010	2006 Survey	Difference	% Difference
Number of Tours	1.55	1.26	0.29	22.6%

Table 12. Percent of Tours by Purpose

Tour Purpose	Percent of Tours (SoundCast 2010)	Percent of Tours (2006 Survey)	Difference
Escort	14.3%	15.7%	-1.4%
Meal	7.1%	4.6%	2.5%
Personal Business	15.4%	11.1%	4.3%
School	14.7%	15.5%	-0.8%
Shop	5.8%	8.2%	-2.4%
Social	16.9%	13.5%	3.4%
Work	25.9%	31.4%	-5.5%

Table 13. Tours per person by purpose

	Tours per Person (SoundCast 2010)	Tours per Person (2006 Survey)	Difference
Escort	0.2	0.2	0%
Meal	0.1	0.1	0%
Personal Business	0.2	0.1	0.10%
School	0.2	0.2	0.10%
Shop	0.1	0.1	0%
Social	0.3	0.2	0%
Work	0.4	0.4	0.10%

Table 14. Trips per Person by Purpose

	Trips per Person (SoundCast 2010)	Trips per Person (2006 Survey)	Difference
Escort	0.5	0.5	0
Meal	0.2	0.2	-0.1
None/Home	1.5	1.5	0
Personal Business	0.6	0.4	0.2
School	0.3	0.2	0
Shop	0.2	0.4	-0.2
Social	0.4	0.2	0.2
Work	0.6	0.6	0.0

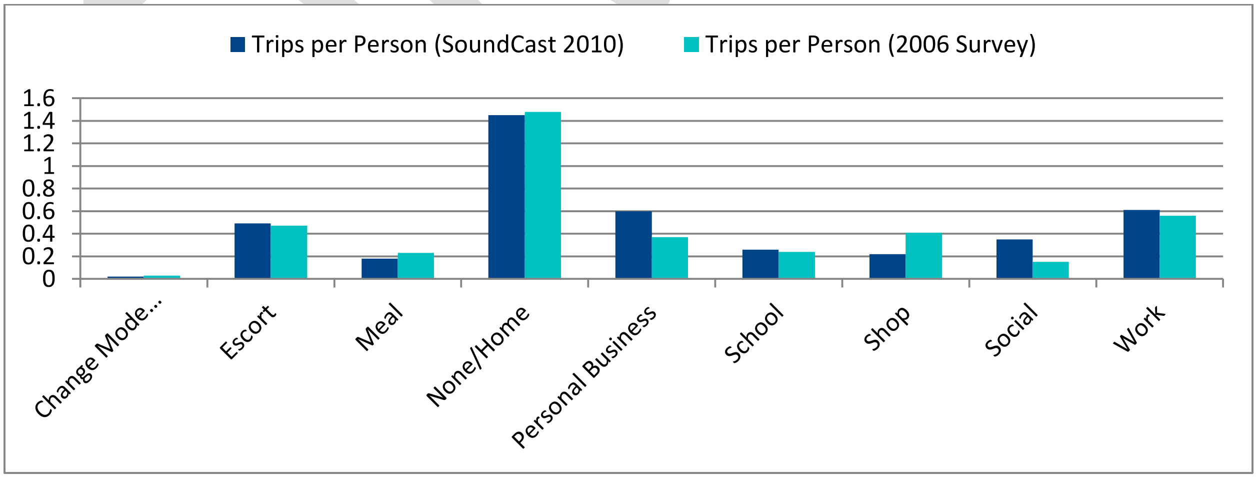

Figure 5. Average Trips per Person by Trip Purpose

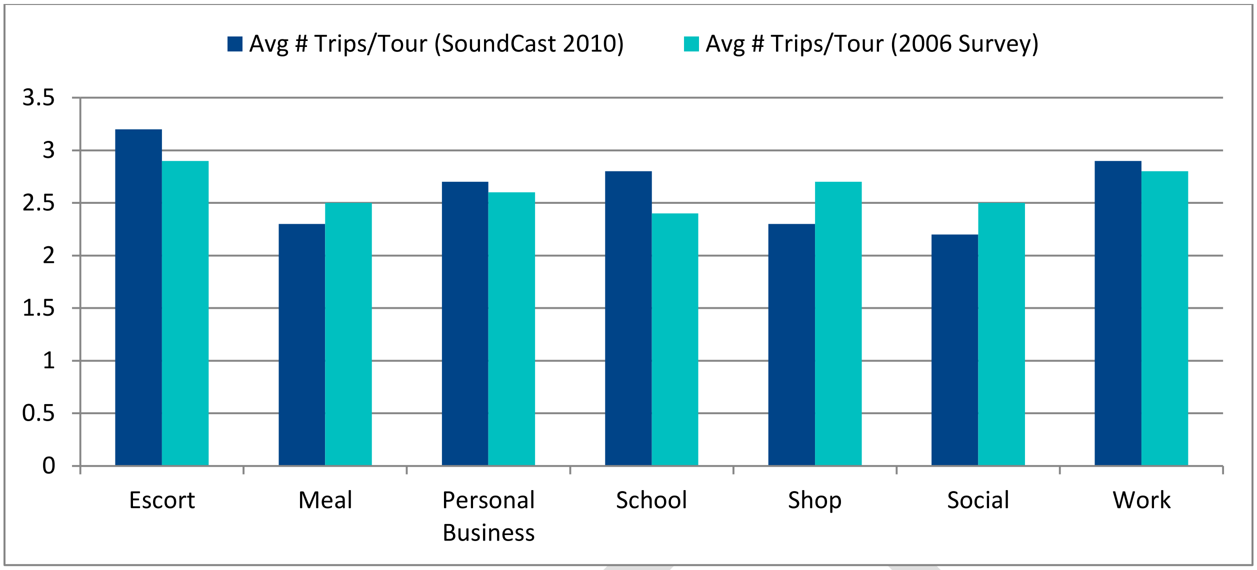

Figure 6. Average Trips per Tour

Table 15. Average trips per tour by tour purpose

Tour Purpose	Avg # Trips/Tour (SoundCast 2010)	Avg # Trips/Tour (2006 Survey)	Difference
Escort	3.2	2.9	0.3
Meal	2.3	2.5	-0.2
Personal Business	2.7	2.6	0
School	2.8	2.4	0.3
Shop	2.3	2.7	-0.4
Social	2.2	2.5	-0.3

Table 16. Average Trips per Tour by Tour Mode

Tour Mode	Avg # Trips/Tour (SoundCast 2010)	Avg # Trips/Tour (2006 Survey)	Difference	% Difference
Bike	2.6	2.4	0.2	7.5%
HOV2	2.8	2.8	-0.1	-2.8%
HOV3+	2.9	2.9	0	0.4%
SOV	2.6	2.7	-0.1	-4.1%
School Bus	2.7	2.3	0.4	15.7%
Transit	2.9	2.6	0.3	11.4%
Walk	2.5	2.2	0.2	10.3%

Other Destination Choice

The other destination choice model selects the parcel where people will go for non-mandatory activities and for irregular work locations. The tables and charts below compare the average tour and trip lengths from the household survey to SoundCast by purpose.

Table 17. Average Tour Length by Purpose

	Average Tour Length (SoundCast 2010)	Average Tour Length (2006 Survey)	Difference	% Difference
Escort	6.4	5.9	0.5	8.2%
Meal	5.1	5.2	0	-0.3%
Personal Business	5.3	6.8	-1.5	-22.3%
School	5	4.5	0.5	11.2%
Shop	4.3	4.9	-0.7	-13.6%
Social	5.1	6.7	-1.6	-23.5%
Work	12.9	12.3	0.6	5.2%

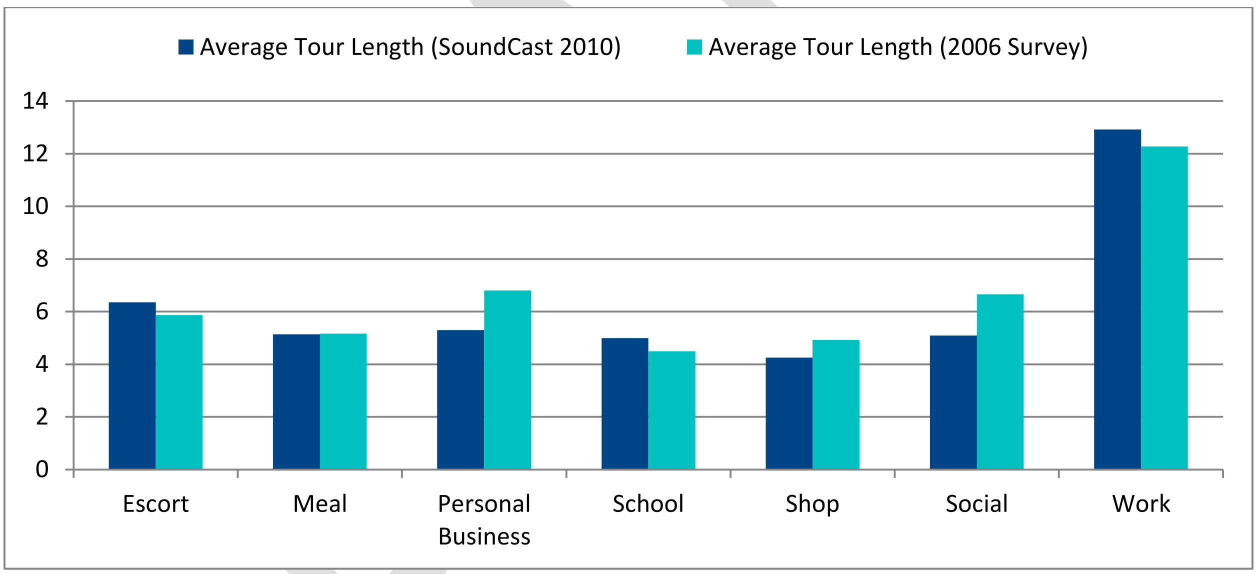

Figure 7. Average Tour Length by Purpose

Table 18. Average Trip Length by Purpose

Trip Purpose	Average Distance (SoundCast 2010)	Average Distance (2006 Survey)	Difference	% Difference
Escort	4.4	5.1	-0.7	-14%
Meal	4.8	3.9	0.9	24%
None/Home	6.9	6.4	0.6	8.80%
Personal Business	4.1	5.4	-1.4	-24.80%
School	4.6	4.1	0.6	14.30%
Shop	4.1	4.3	-0.3	-6.50%
Social	4.7	5.7	-1	-17.50%
Work	10	9.8	0.2	2.50%

Table 19. Average Distance by Trip Mode

Trip Mode	Average Distance (SoundCast 2010)	Average Distance (2006 Survey)	Difference	% Difference
Bike	4	4.6	-0.6	-12.6%
HOV2	5.4	5.9	-0.6	-9.9%
HOV3+	5.2	5.2	0	-0.3%
SOV	7.1	7.5	-0.4	-5.3%
School Bus	4.0	3.8	0.2	5.0%
Transit	8.4	8	1.4	6.5%
Walk	1.2	1	0.3	26.3%

The following tables show which destinations the model selects as locations for activities as compared to the household survey. Note that Table 22 shows large discrepancies between the household survey and the number of people by home district. The discrepancies are caused by 1. change over time (the survey was 2006, the model was 2010), 2. the survey was not controlled to districts for its expansion factors; the lowest geographic control was county, 3. the model numbers are the results of a synthetic population generation process. Because of the large differences in persons, we cannot expect the model would predict the number of trips from the survey closely.

Table 20. Percent of Tours by Destination District

Destination District Name	% of Tours (SoundCast 2010)	% of Tours (2006 Survey)	Difference	% Difference
East Side	17.7%	18.4%	-0.7%	-4.0%
Everett-Lynwood-Edmonds	8.4%	8.7%	-0.3%	-3.8%
Kitsap	6.0%	6.2%	-0.2%	-3.3%
North Seattle-Shoreline	9.0%	11.5%	-2.5%	-22.0%
Renton-FedWay-Kent	16.7%	13.6%	3.1%	23.0%
S.Kitsap	1.1%	1.4%	-0.3%	-22.2%
Seattle CBD	7.8%	9.6%	-1.8%	-18.4%
South Pierce	10.8%	10.1%	0.7%	6.9%
Suburban Snohomish	9.1%	8.0%	1.1%	13.5%
Tacoma	6.7%	6.8%	-0.1%	-1.3%
West-South Seattle	6.8%	5.7%	1.1%	18.7%

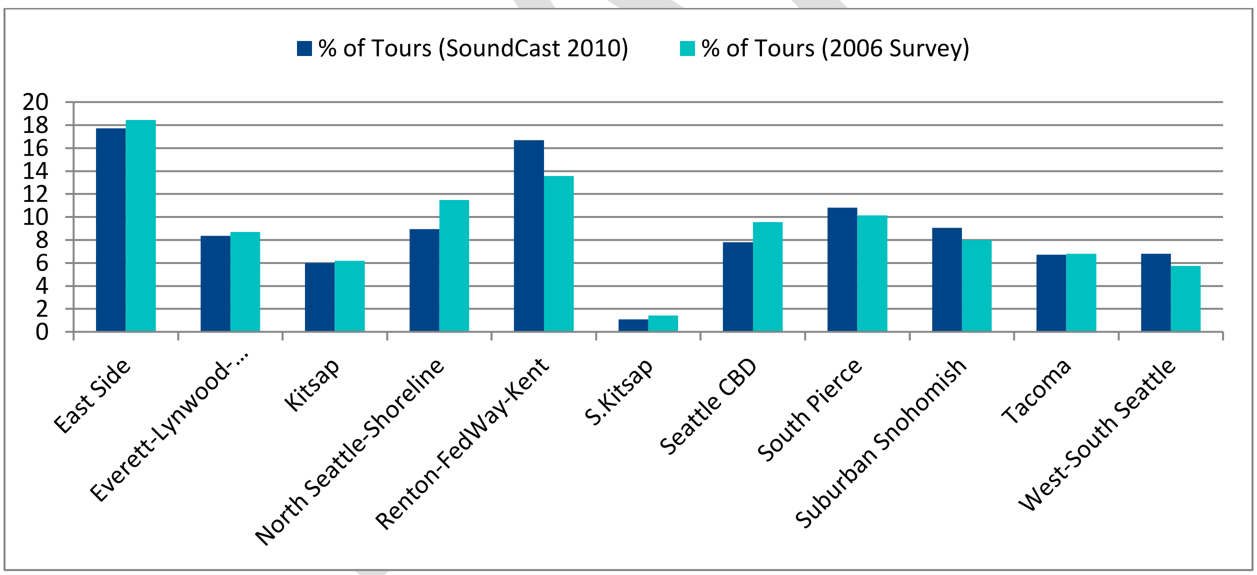

Figure 8. Percent of Tours by Destination District

Table 21. Percent of Trips by Destination District

Destination District	% of Trips (SoundCast 2010)	% of Trips (2006 Survey)	Difference	% Difference
East Side	17.5%	18.6%	-1.1%	-6.0%
Everett-Lynwood-Edmonds	8.0%	9.0%	-1.0%	-10.8%
Kitsap	6.1%	6.5%	-0.4%	-6.6%
North Seattle-Shoreline	9.0%	12.1%	-3.1%	-25.6%
Renton-FedWay-Kent	16.2%	13.2%	3.0%	22.6%
S.Kitsap	1.3%	1.4%	-0.1%	-9.9%
Seattle CBD	6.7%	7.0%	-0.3%	-4.9%
South Pierce	11.5%	10.0%	1.5%	14.4%
Suburban Snohomish	10.1%	9.9%	0.2%	2.0%
Tacoma	6.6%	6.3%	0.3%	4.2%
West-South Seattle	6.6%	5.9%	0.7%	11.9%

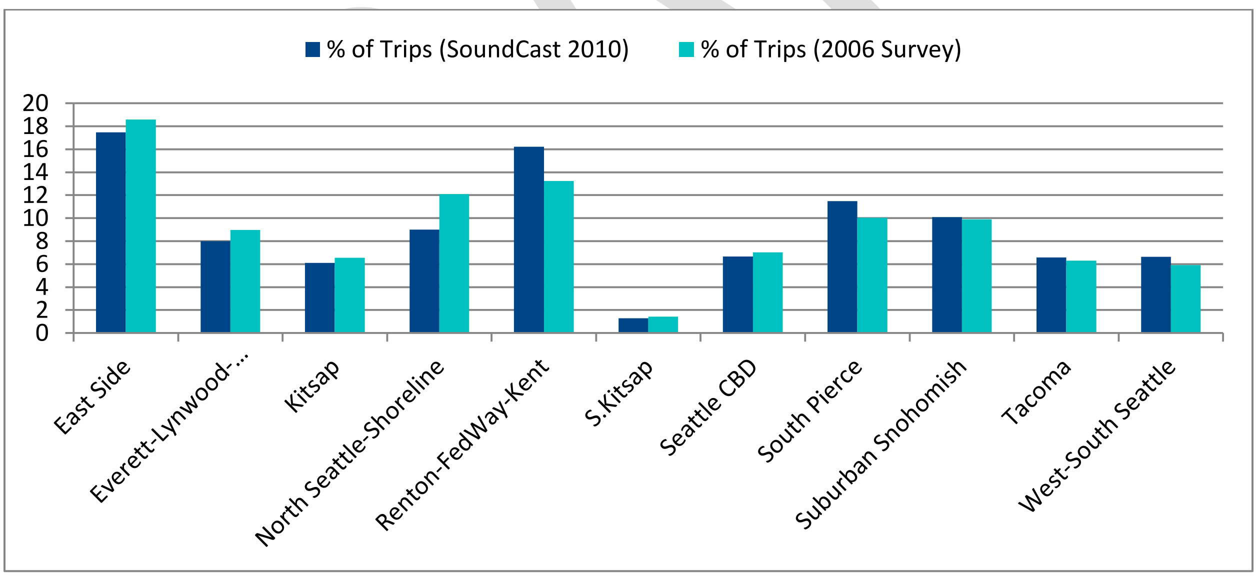

Figure 9. Percent of Trips by Destination District

Table 22. Number of People by Home District

Home District	Number of People (SoundCast 2010)	Number of People (2006 Survey)	Difference (People)	% Difference (People)
East Side	611,001	585,902	25,099	4.3%
Everett-Lynwood-Edmonds	266,633	250,955	15,678	6.3%
Kitsap	245,547	235,772	9,775	4.2%
North Seattle-Shoreline	310,226	380,782	(70,556)	-18.5%
Renton-FedWay-Kent	559,730	414,589	145,141	35.0%
S.Kitsap	62,578	69,971	(7,393)	-10.6%
Seattle CBD	169,722	134,069	35,653	26.6%
South Pierce	469,960	403,346	66,614	16.5%
Suburban Snohomish	433,112	383,631	49,481	12.9%
Tacoma	231,982	221,325	10,657	4.8%
West-South Seattle	236,048	186,700	49,348	26.4%

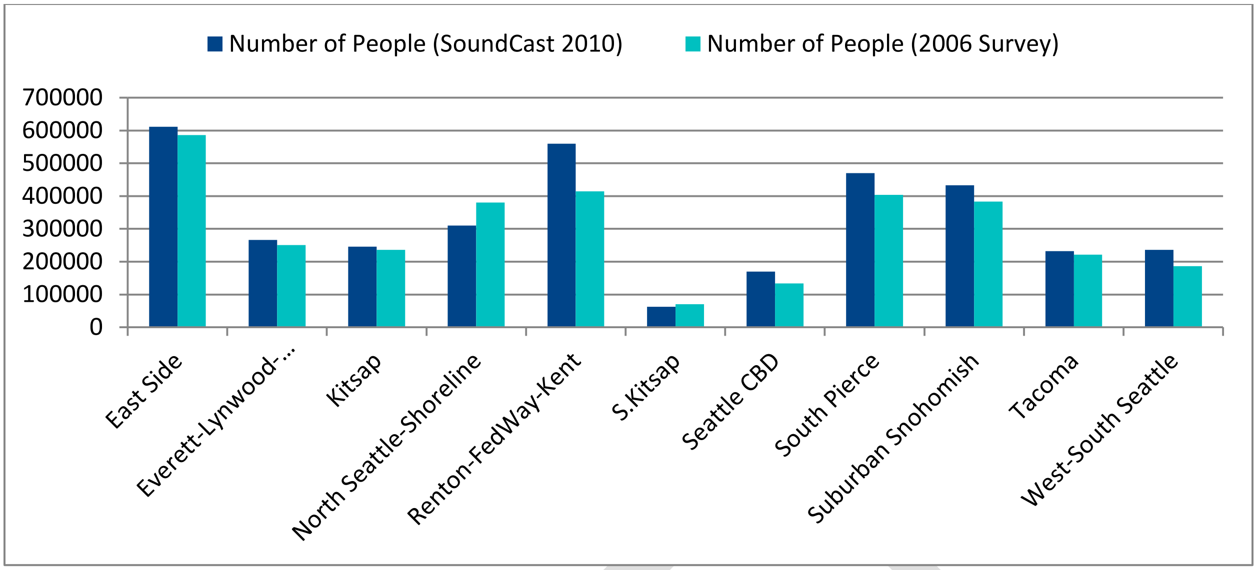

Figure 10. Number of People by Home District

Table 23 and Table 24 compare the district to district trips generated by the model and observed in the survey.

Table 23. SoundCast Trips Origin District by Destination District

Origin/Destination	East Side	Everett-Lynwood-Edmonds	Kitsap	North Seattle-Shoreline	Renton-FedWay-Kent	S.Kitsap	Seattle CBD	South Pierce	Suburban Snohomish	Tacoma	West-South Seattle
East Side	2,198,891	33,102	1,288	65,968	118,431	291	51,359	8,016	97,431	4,438	37,235
Everett-Lynwood-Edmonds	32,946	850,334	1,511	85,547	6,093	47	14,845	1,125	199,328	763	6,920
Kitsap	1,292	1,534	875,913	1,696	1,267	26,913	906	2,306	538	2,964	2,152
North Seattle-Shoreline	66,215	85,429	1,666	923,025	21,758	197	163,089	3,586	38,357	2,335	37,288
Renton-FedWay-Kent	118,039	6,168	1,334	21,751	1,882,608	3,262	37,955	114,752	9,268	74,694	158,821
S.Kitsap	308	43	26,955	189	3,259	140,567	125	8,582	41	13,399	456
Seattle CBD	51,426	14,897	837	163,536	37,740	111	556,927	6,780	15,750	4,291	118,273
South Pierce	7,978	1,148	2,267	3,556	114,789	8,554	6,842	1,314,187	1,097	251,932	9,529
Suburban Snohomish	97,323	199,056	557	38,223	9,368	38	15,881	1,111	1,139,906	880	7,594
Tacoma	4,332	745	3,033	2,398	74,599	13,487	4,189	252,096	871	620,872	7,425
West-South Seattle	37,750	6,952	2,131	37,104	158,793	459	117,992	9,409	7,477	7,465	605,380

Table 24. Household Survey Trips Origin District by Destination District

Origin/Destination	East Side	Everett-Lynwood-Edmonds	Kitsap	North Seattle-Shoreline	Renton-FedWay-Kent	S.Kitsap	Seattle CBD	South Pierce	Suburban Snohomish	Tacoma	West-South Seattle
East Side	2,045,596	37,579	1,900	58,329	82,437	587	79,991	4,353	86,026	4,134	29,459
Everett-Lynwood-Edmonds	38,190	841,539	3,869	75,129	5,409	-	19,063	247	185,234	2,332	6,086
Kitsap	1,791	3,847	806,996	2,510	2,580	15,639	6,271	3,881	1,359	6,612	1,584
North Seattle-Shoreline	55,329	76,841	2,909	1,191,989	24,659	368	150,176	949	28,316	1,664	42,915
Renton-FedWay-Kent	88,323	5,120	2,608	19,984	1,351,332	3,079	30,389	80,621	3,085	50,292	90,232
S.Kitsap	309	-	15,290	487	3,630	142,994	605	4,615	-	19,126	99
Seattle CBD	77,468	17,860	6,570	156,740	30,222	693	533,154	2,988	12,481	4,329	81,569
South Pierce	5,100	197	4,763	1,159	85,100	4,101	3,259	1,057,527	1,472	143,138	5,571
Suburban Snohomish	85,613	182,275	1,293	25,687	2,556	-	11,094	1,667	968,105	430	4,265
Tacoma	3,110	1,639	7,112	2,442	49,126	19,749	4,143	147,529	1,051	586,209	4,794
West-South Seattle	27,813	5,662	1,906	44,730	91,407	99	77,248	7,226	5,584	5,306	506,476

MODE CHOICE

Several models predict mode choice in SoundCast first at the tour level and then the trip level. The tour mode choice is divided by purpose: work, school, work-based, escort, and other (social, personal business, meal, shopping). It was found during calibration that the 2006 survey estimated a higher share of transit use than was implied by the observed boardings for the transit service providers. Thus the transit mode shares we decreased as compared to the survey since the observed transit boardings are a more accurate comprehensive measure (they are a count of boardings as opposed to a sample of households).

Table 25. Tour Mode Choice Shares

Tour Mode	SoundCast 2010 Share (%)	2006 Survey Share (%)	Difference
Bike	0.9%	1%	-0.1%
HOV2	23.4%	20.8%	2.5%
HOV3+	20.6%	23.4%	-2.8%
Drive Transit	0.7%	1.7%	-1%
SOV	39.6%	37%	2.7%
School Bus	4.8%	5.2%	-0.4%
Walk Transit	3.2%	4.1%	-0.8%
Walk	6.8%	6.8%	0%

Table 26. Work, School, and Escort Tour Mode Share by Purpose

	Work (SoundCast 2010)	Work (2006 Survey)	School (SoundCast 2010)	School (2006 Survey)	School (SoundCast 2010)	School (2006 Survey)
Walk	2.2%	1.8%	8.6%	7.7%	5.2%	7.1%
Transit	7.3%	7.5%	3.3%	3.7%	0.0%	0.5%
HOV2	12.9%	14.2%	14.6%	12.7%	39.2%	36.3%
SOV	67.8%	62.8%	9.9%	9.2%	1.6%	1.1%
Bike	1.0%	1.5%	1.5%	1.2%	0.3%	0.1%
HOV3+	6.1%	8.1%	29.5%	29.5%	53.6%	54.8%
School Bus			32.7%	35.1%		

Table 27. Other Tour Mode Choice Shares

	Personal Business (SoundCast 2010)	Personal Business (2006 Survey)	Social (SoundCast 2010)	Social (2006 Survey)	Meal (SoundCast 2010)	Meal (2006 Survey)	Shop (SoundCast 2010)	Shop (2006 Survey)
Walk	4.3%	7.2%	12.3%	13.6%	12.7%	16.2%	9.7%	7.3%
Transit	2%	4.4%	1.9%	2.1%	1.6%	0.4%	2%	2.6%
HOV2	23.4%	21.6%	29.3%	21.9%	35.4%	28.3%	21.3%	25.5%
SOV	54.7%	48.1%	39%	31.7%	31.6%	27.6%	54.7%	50.3%
Bike	1%	0.4%	0.8%	1.8%	0.5%	0.4%	1.1%	0.4%
HOV3+	14.6%	16.9%	16.8%	28.2%	18.2%	26.7%	11.3%	13.5%

The trip mode choice model predicts the share of trips by each mode, but is highly dependent on the tour mode that has been previously selected. Table 29 and Table 28 show the percent of trips by mode given tour mode from the model and the survey. Note that the model only allows certain combinations of trip mode and tour mode based on a hierarchy (only the lower diagonal are possible combinations). For example, if a tour's mode is school bus, only school bus is allowed as the trip mode. Some rare tour mode-trip mode combinations were observed in the survey but we don't model them to simplify the model for understandability and model run time.

Table 28. Trip Mode by Tour Mode 2010 SoundCast

Tour Mode -> Trip Mode	Drive Transit	Transit	School Bus	HOV3+	HOV2	SOV	Bike	Walk
Drive Transit	0%	0%	0%	0%	0%	0%	0%	0%
Transit	42.6%	56.2%	0%	0%	0%	0%	0%	0%
School Bus	0%	0%	55%	0%	0%	0%	0%	0%
HOV3+	0%	1.9%	12.9%	81.8%	0%	0%	0%	0%
HOV2	1.4%	6.5%	30.5%	6.5%	76.6%	0%	0%	0%
SOV	56%	13.8%	0.7%	11.2%	22.8%	99.8%	0%	0%
Bike	0%	0%	0%	0%	0%	0%	85.1%	0%
Walk	0%	21.6%	0.9%	0.4%	0.6%	0.2%	14.9%	100%

Table 29. Trip Mode by Tour Mode 2006 Survey

Mode Share by Tour Mode (2006 Survey) (%)								
Tour Mode -> Trip Mode	**Drive Transit**	**Transit**	**School Bus**	**HOV3+**	**HOV2**	**SOV**	**Bike**	**Walk**
Drive Transit	5.4%	0%	0%	0%	0%	0%	0.1%	0%
Transit	34.8%	59.4%	0.6%	0.2%	0.4%	0.3%	1%	1%
School Bus	0.1%	0.1%	63.5%	0.2%	0.1%	0%	0%	0%
HOV3+	4.4%	4.3%	18.4%	64.9%	3.9%	2.5%	3.5%	4.8%
HOV2	9.3%	9.5%	13.7%	15.2%	62.9%	5%	3.1%	4.6%
SOV	41.6%	5.9%	0.7%	15.9%	29%	89.9%	7.4%	6.8%
Bike	0.2%	1%	0.1%	0.2%	0.2%	0.2%	76.3%	0.6%
Walk	4.2%	19.8%	3%	3.3%	3.4%	2.1%	8.6%	82.2%

The following table shows how the average distance (as skimmed on the auto network) varies across mode. Walk trips are substantially shorter than drive to transit, as one would expect.

Table 30. Average Auto Distance (miles) by Tour Mode

Tour Mode	Mean Auto Distance (SoundCast 2010)	Mean Auto Distance (2006 Survey)
Bike	4.6	4.8
HOV2	7	7.7
HOV3+	6.6	6.3
Drive Transit	18.5	16.7
SOV	8.8	9.5
School Bus	4.4	3.7
Walk Transit	8	8
Walk	1.4	1

Table 31 shows the overall trip mode share from SoundCast as compared to the 2006 survey. SOV shares are intentionally slightly higher to account for underreporting and match counts.

Table 31. Trip Mode Share

Trip Mode	Mode Share (SoundCast 2010) (%)	Mode Share (2006 Survey) (%)
Bike	0.8%	0.9%

HOV2	21.5%	21.8%
HOV3+	18.7%	20%
SOV	46.6%	43.5%
School Bus	2.6%	2.7%
Transit	2.5%	2.5%
Walk	7.4%	8.4%

Time Choice

Figure 11. Trip Arrival Times by Hour compares the trip arrival times by hour from the model and the survey. The model is predicting more travel in the late night and mid-day, and the survey shows more travel in the peaks and in the evening. This discrepancy could be problematic for calculating delay and hourly volumes. However, the model was mostly calibrated to match vehicle counts by time as shown in Figure 15. More investigation is required to understand why the survey and the observed counts by hour would be different.

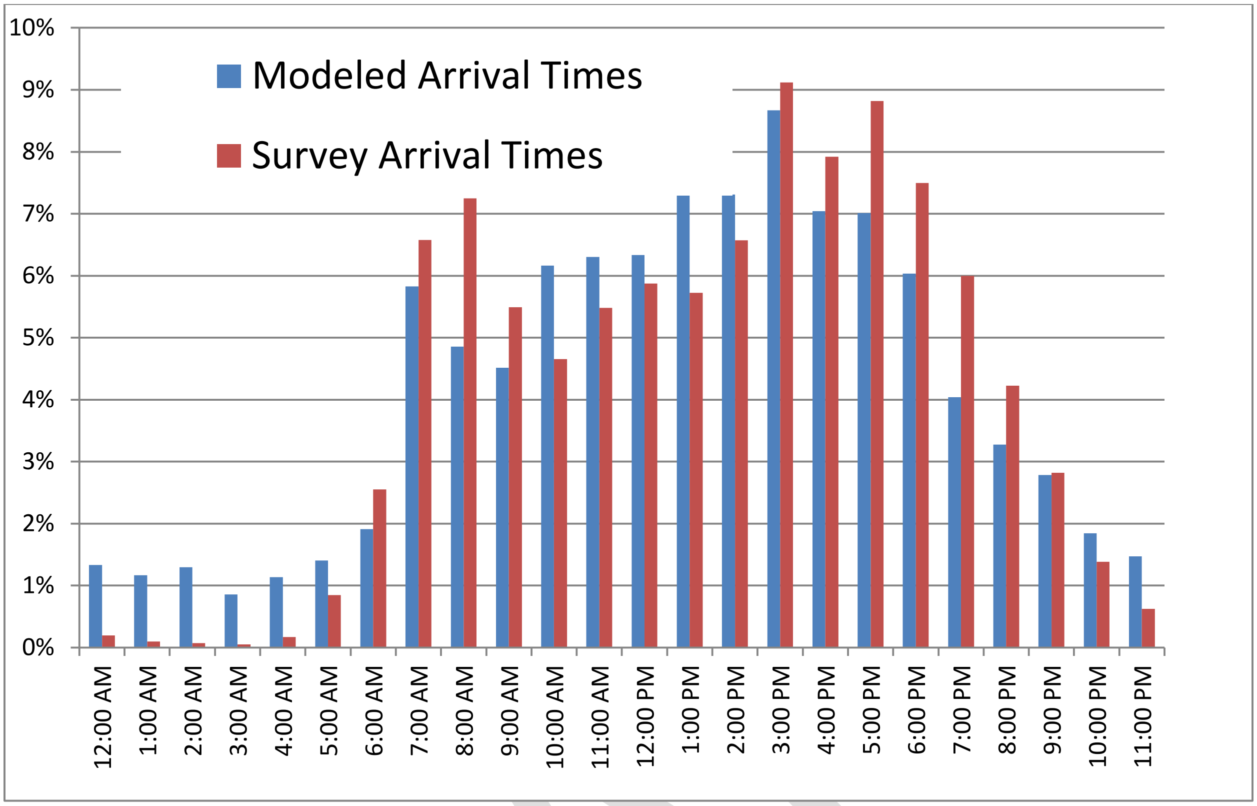

Figure 11. Trip Arrival Times by Hour

HIGHWAY ASSIGNMENT

Figure 12, Figure 13, and Figure 14 compare the model to observed counts on 1. freeways with loop detectors, 2. arterials, and 3. state highways without loop detectors.

The model matches the freeways with loop detectors quite well (R^2 = 0.93). However, the model is slightly higher than counts on freeways. The model does not match the arterial counts as well as the freeways, as is to be expected with smaller facility types. Finally the model is slightly lower on state highways than observed. This may indicate that the model does not have enough suburban and rural activity and should be looked into further.

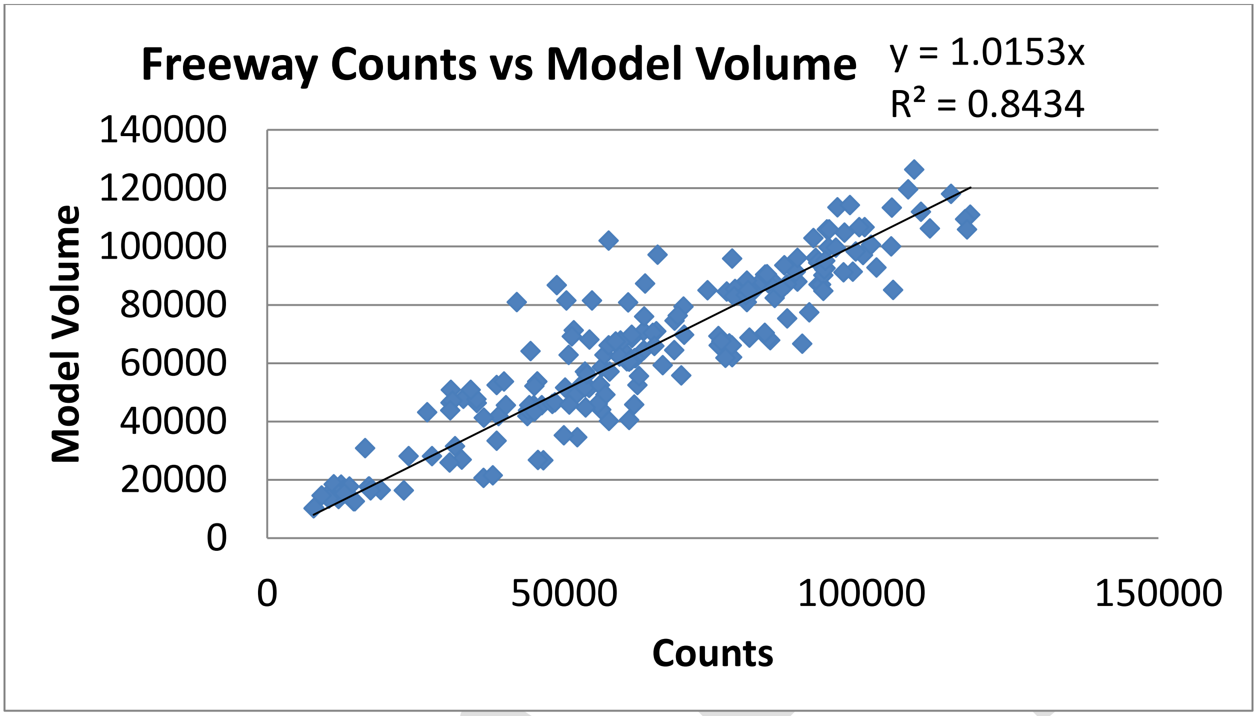

Figure 12. Freeway Loop Detector Counts vs Modeled Volumes

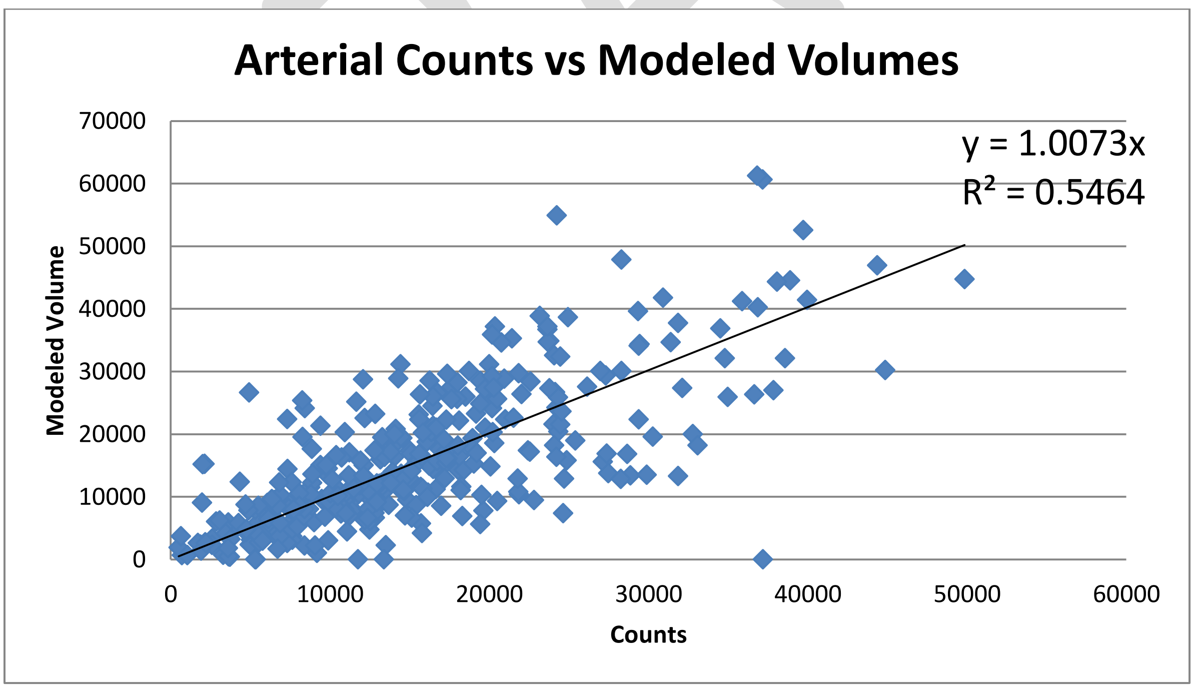

Figure 13. Arterial Counts vs Modeled Volumes

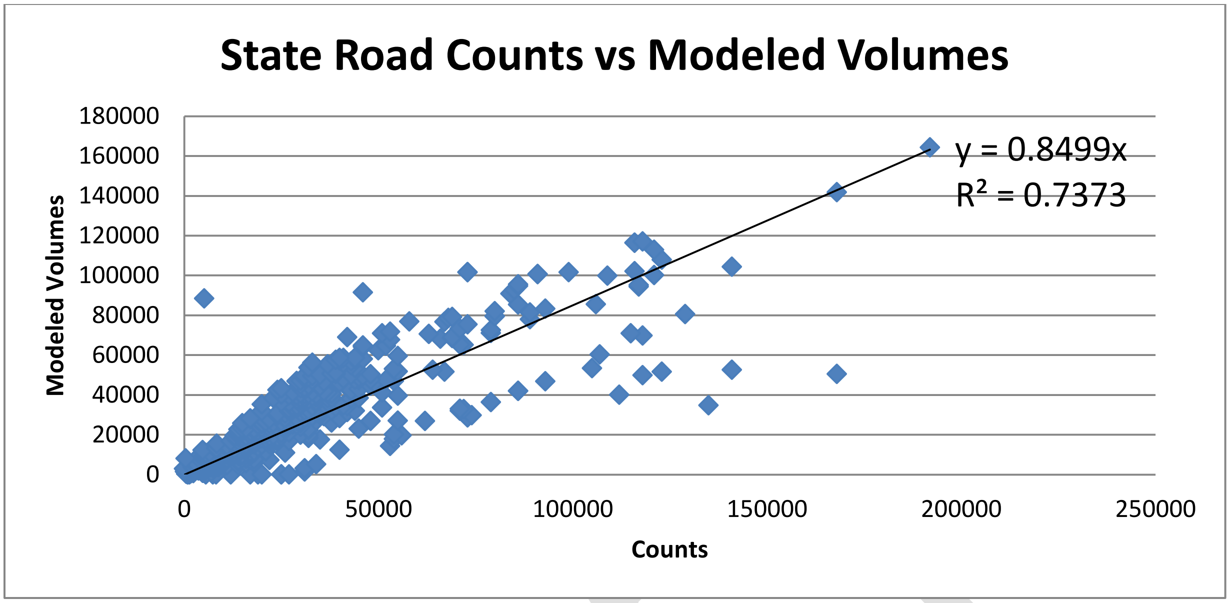

Figure 14. State Road Counts vs Modeled Volumes (for Freeways without loop detectors, more rural and suburban)

Table 32 compares the model to counts by highway time period. The modeled volumes are within 10% of the counted volumes for each time period.

Table 32. Modeled Volumes vs Counts by Time Period

Time Period	Counts (Model Run)	Counts (Observed)	Difference	% Difference
5 to 6	410,200	416,600	-6,500	-1.56%
6 to 7	655,700	693,000	-37,300	-5.38%
7 to 8	774,300	810,100	-35,800	-4.42%
8 to 9	693,500	760,700	-67,200	-8.83%
9 to 10	696,200	721,000	-24,800	-3.44%
10 to 14	2,772,000	2,893,000	-121,000	-4.18%
14 to 15	779,100	825,200	-46,100	-5.58%
15 to 16	843,600	872,600	-29,000	-3.32%
16 to 17	829,100	882,500	-53,400	-6.05%
17 to 18	880,400	863,900	16,600	1.92%
18 to 20	1,256,600	1,367,800	-111,200	-8.13%
20 to 5	2,019,200	2,098,800	-79,600	-3.79%

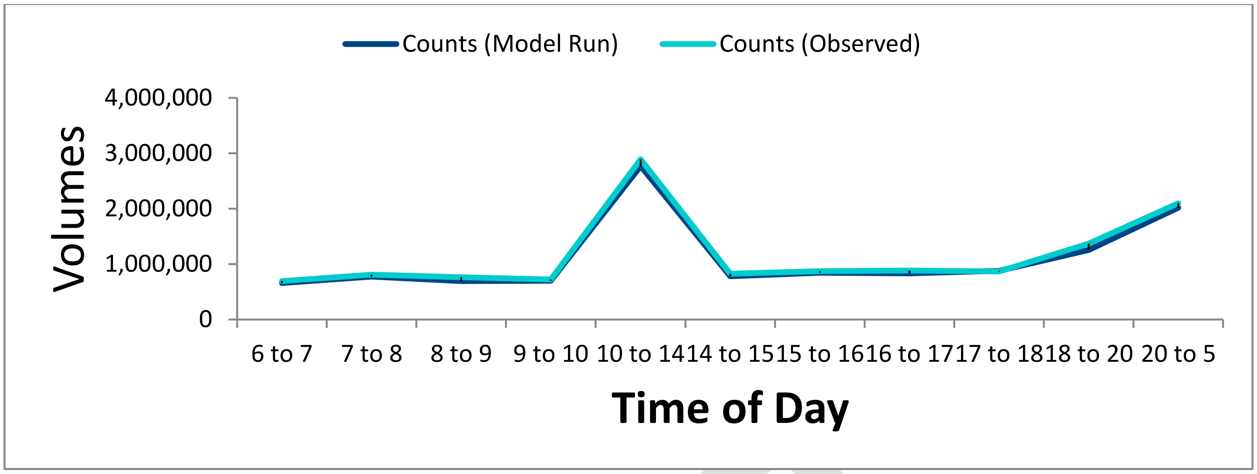

Figure 15. Modeled Counts vs Volumes by Time of Day

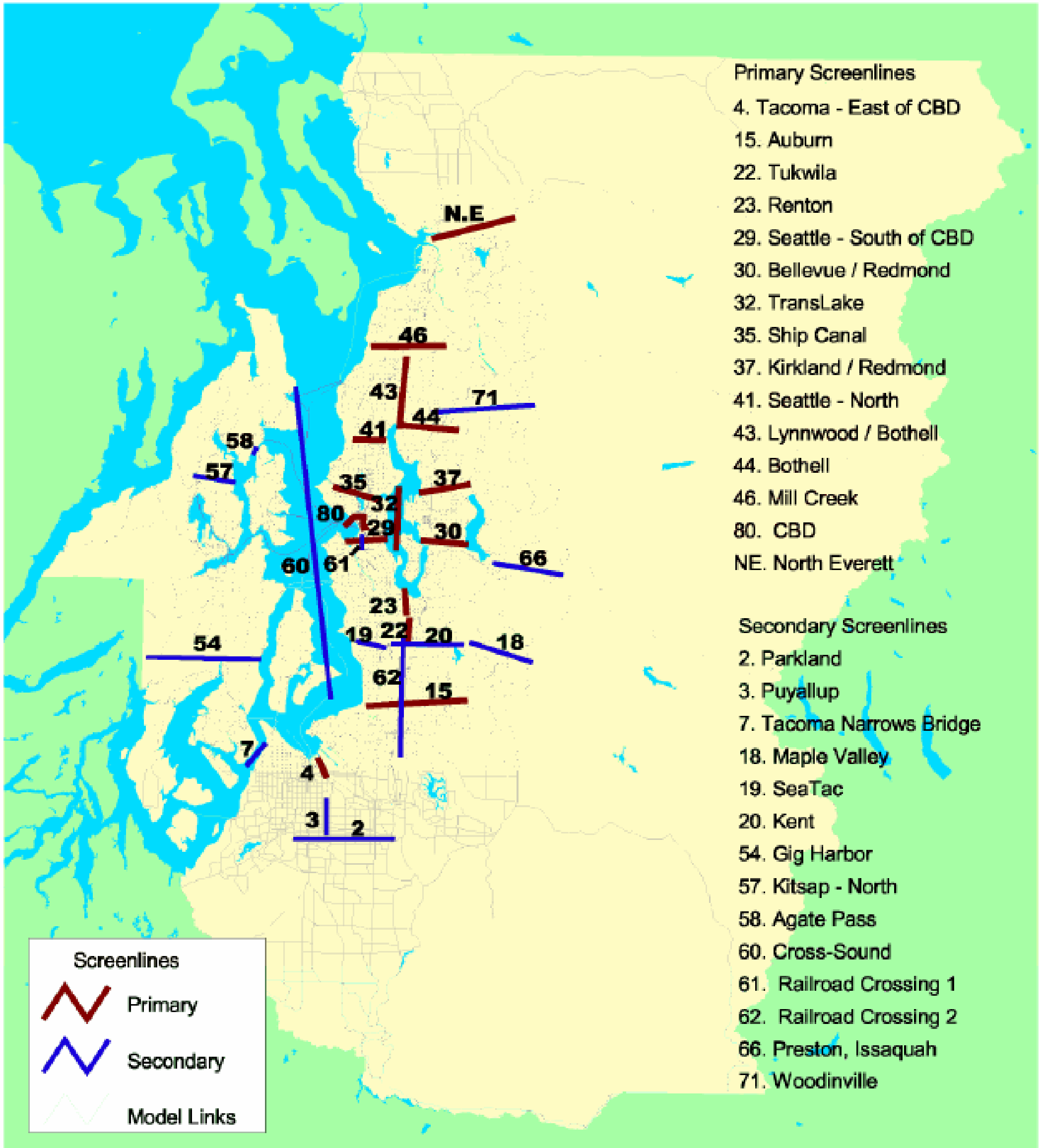

Figure 16. PSRC Screenlines

Figure 16. PSRC Screenlines shows the locations of screenlines in the PSRC region. The tables compare the model to observed volumes across these screenlines. One area of concern is that travel in Kitsap overall is too high (Gig Harbor, Tacoma Narrows, and Cross Sound).

Table 33. Modeled vs Observed Volume by Primary Screenline

Primary Screenline	Screenline	Modeled Volume	Observed Volume	Est/Obs	Difference	% Difference
Auburn	14/15	545,900	534,800	1.02	11,000	2.07%

Bellevue/Redmond	30	355,100	354,600	1.00	500	0.13%
Bothell	44	289,900	255,600	1.13	34,300	13.43%
Kirkland/Redmond	37	412,100	381,300	1.08	30,700	8.06%
Lynnwood/Bothell	43	265,200	231,400	1.15	33,800	14.63%
Mill Creek	46	372,900	350,500	1.06	22,400	6.38%
Renton	23	75,400	81,800	0.92	-6,300	-7.76%
Seattle - North	41	366,300	327,000	1.12	39,300	12.01%
Ship Canal	35	547,200	521,200	1.05	26,000	4.99%
Tacoma - East of CBD	4	304,300	271,800	1.12	32,600	11.98%
TransLake	32	246,500	250,200	0.99	-3,700	-1.48%
Tukwila	22	224,600	239,500	0.94	-14,900	-6.23%
Total		**4,005,500**	**3,799,700**	**1.05**	**205,700**	**5.4%**

Table 34. Modeled vs Observed Volume by Secondary Screenline

Secondary Screenline	Screenline	Modeled Volume	Observed Volume	Est/Obs	Difference	% Difference
Agate Pass	58	22,500	21,000	1.07	1,500	7.05%
Cross-Sound	60	23,400	17,500	1.34	5,900	33.74%
Gig Harbor	54	82,000	58,500	1.40	23,500	40.22%
Kent	20	526,200	504,600	1.04	21,600	4.28%
Kitsap - North	57	78,700	97,200	0.81	-18,500	-19.03%
Maple Valley	18	55,400	61,900	0.89	-6,500	-10.54%
Parkland	2	269,200	285,900	0.94	-16,700	-5.84%
Preston, Issaquah	66	89,600	93,200	0.96	-3,700	-3.92%
Puyallup	3	110,300	118,700	0.93	-8,400	-7.10%
SeaTac	19	92,300	71,400	1.29	20,900	29.35%
Tacoma Narrows	7	83,800	79,000	1.06	4,800	6.03%
Woodinville	71	114,900	98,300	1.17	16,500	16.81%
Total		**1,548,300**	**1,507,200**	**1.03**	**41,100**	**2.71%**

Transit Assignment

Table 35 and Table 36 shows modeled and observed boardings in the AM and MD by transit type. More work needs to be done to improve the ferry estimates.

Table 35. AM Modeled vs Observed Boardings

Transit Type	Modeled AM Boardings	Observed AM Boardings	Difference	% Difference
Community Transit	10,661	7,998	2,663	33.30%
Commuter Rail	6,086	4,676	1,410	30.14%
Everett Transit	1,926	1,388	538	38.74%
Ferry	453	2,500	-2,047	**-81.87%**
King County Metro	77,048	79,129	-2,081	-2.63%
Kitsap Transit	2,166	3,085	-920	-29.81%
Light Rail	3,308	3,392	-84	-2.48%
Monorail	24	1,596	-1,572	**-98.50%**
Pierce Transit	12,331	8,269	4,062	49.12%
Sound Transit Express	12,511	12,111	401	3.31%
Total	126,514	124,144	2,369	1.91%

Table 36. Mid-day Modeled and Observed Transit Boardings

Transit Type	Modeled MD Boardings	Observed MD Boardings	Difference	% Difference
Community Transit	11,379	9,679	1,700	17.56%
Everett Transit	2,035	3,236	-1,201	-37.11%
Ferry	799	1,501	-702	-46.78%
King County Metro	111,946	113,886	-1,941	-1.70%
Kitsap Transit	1,759	3,164	-1,405	-44.41%
Light Rail	4,255	7,079	-2,824	-39.89%
Monorail	24	2,310	-2,286	**-98.97%**
Pierce Transit	19,039	19,931	-891	-4.47%
Sound Transit Express	21,827	10,853	10,974	**101.11%**
Total	173,063	171,639	1,424	0.83%

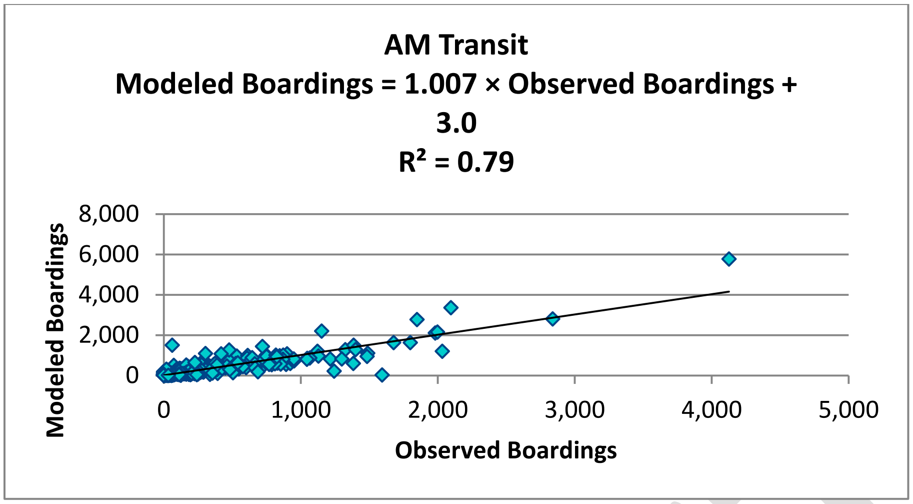

Figure 17. AM Modeled vs Observed Boardings by Route

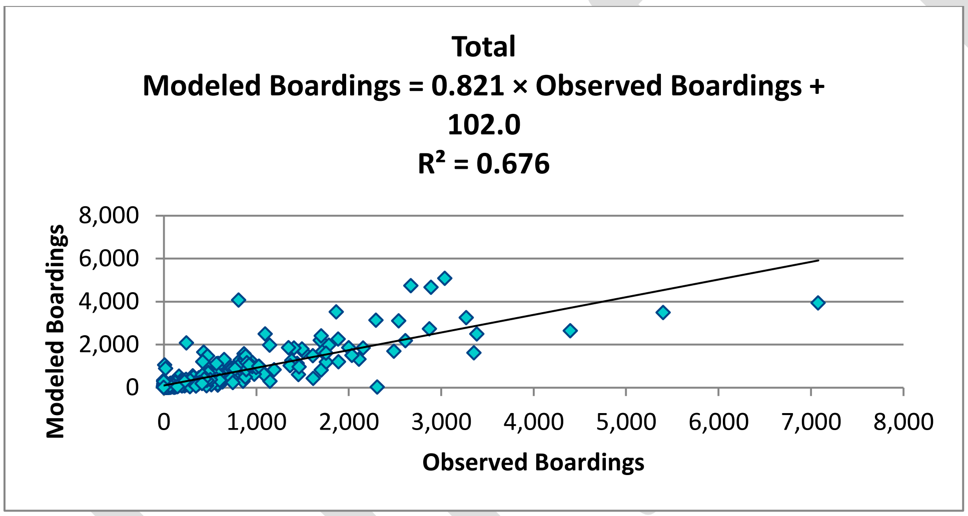

Figure 18. MD Modeled vs Observed Boardings by Route

Sensitivity Tests

Several sensitivity tests have been run on the model. The model has undergone minor improvements after some of these tests, but the results should be largely similar with today's model as they were previously.

Tacoma Narrows and Tolling

Because the current regional transportation plan calls for extensive highway tolling to pay for transportation improvements and relieve congestion, it is essential that the model respond reasonably to highway pricing.

A year 2010 sensitivity test was performed that removed the tolls. Tolling began on the Tacoma Narrows in July 2007, so in reality in 2010 there were tolls. With this test we were looking at the comparison of volumes and speeds on the network with and without tolling on the Narrows. We compared the observed volumes before and after tolling to the modeled volumes before and after tolling.

The average on SR-16 for 2005 was 85,000. We are using 2005 (as opposed to 2007) for comparison because leading up to the tolling, construction was going on that could have impacted volumes. The volume in 2008 was 77,000. This is about a ***9% observed decrease after tolling the Narrows.*** We can't fully attribute this change to tolling, of course, because of the recession that began around the same time as tolling was instituted. Also other transportation and land use changes were occurred as well that could impact these numbers. But it would be fair to say that the order of magnitude of change expected from tolling only would be expected to be in the range of a 5% to 15% decrease.

Table 37. Observed Volumes on SR-16 before and after tolling

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2 013
SR-16: Annual Traffic Report Volumes	85,000	86,000	85,000	82,000	83,000	77,000	79,000	79,000	78,000	77,000	77,000

SoundCast results

The table below shows the volumes in the base scenario and the no toll scenario, both run on a 2010 network and land use. **The no toll scenario resulted in a modeled screenline volume of 115,900, whereas the toll scenario had a volume of 101,200. This is a 13% increase in modeled volume by removing the toll.** This reduction seems fairly reasonable, maybe a little too much reduction. One thing to note is that the model is fairly high on the Tacoma Narrows to start with; the observed screenline volume was 87,800. **The cross-sound screenline decreased 17% when the toll was removed, as is reasonable.** As you can see, the other screenlines didn't change too much, which one would expect.

Table 38. Screenline volumes with and without tolling the Tacoma Narrows

Primary Screenline	**Screenline**	**Modeled Volume-- NO TOLL**	**Modeled Volume - BASE WITH TOLL**	**Observed Volume**
Auburn	14/15	546,200	544,500	509,600
Bellevue/Redmond	30	363,900	364,300	370,000
Bothell	44	294,300	294,000	266,000
Kirkland/Redmond	37	405,100	403,400	451,200
Lynnwood/Bothell	43	279,600	277,800	265,900
Mill Creek	46	371,600	373,200	360,200
Renton	23	75,900	75,400	65,700
Seattle - North	41	361,400	362,000	368,800
Seattle - South of CBD	29	639,400	640,000	638,400
Ship Canal	35	558,000	558,500	537,900
Tacoma - East of CBD	4	314,000	310,000	297,700
TransLake	32	291,400	290,900	265,600
Tukwila	22	228,600	228,200	223,900
	Total	4,729,400	4,722,200	4,471,900
Secondary Screenline	Screenline	Modeled Volume-- NO TOLL	Modeled Volume - BASE WITH TOLL	Observed Volume
Agate Pass	58	20,900	20,300	20,000
Cross-Sound	**60**	**15,500**	**18,200**	**25,200**
Gig Harbor	54	83,900	79,600	60,100
Kent	20	526,000	525,100	504,600
Kitsap - North	57	77,200	76,700	106,800
Maple Valley	18	58,800	58,800	59,000
Parkland	2	263,300	259,900	261,100
Preston, Issaquah	66	88,500	87,500	84,700
Puyallup	3	110,000	108,000	130,500
SeaTac	19	92,500	92,600	67,000
Tacoma Narrows	**7**	**115,900**	**101,200**	**87,800**
Woodinville	71	114,700	114,800	99,400
	Total	1,567,200	1,542,700	1,506,200

When the toll was removed, VMT increased by 593,200 (total VMT was 80,012,700), a 0.75% increase in VMT. This strikes me as a large but reasonable VMT change. Transit didn't change much.
This map shows the difference between the volume in 7-8 am in the toll and no toll scenario. Green means more volume in the no toll scenario. Red means less volume in the no toll scenario.

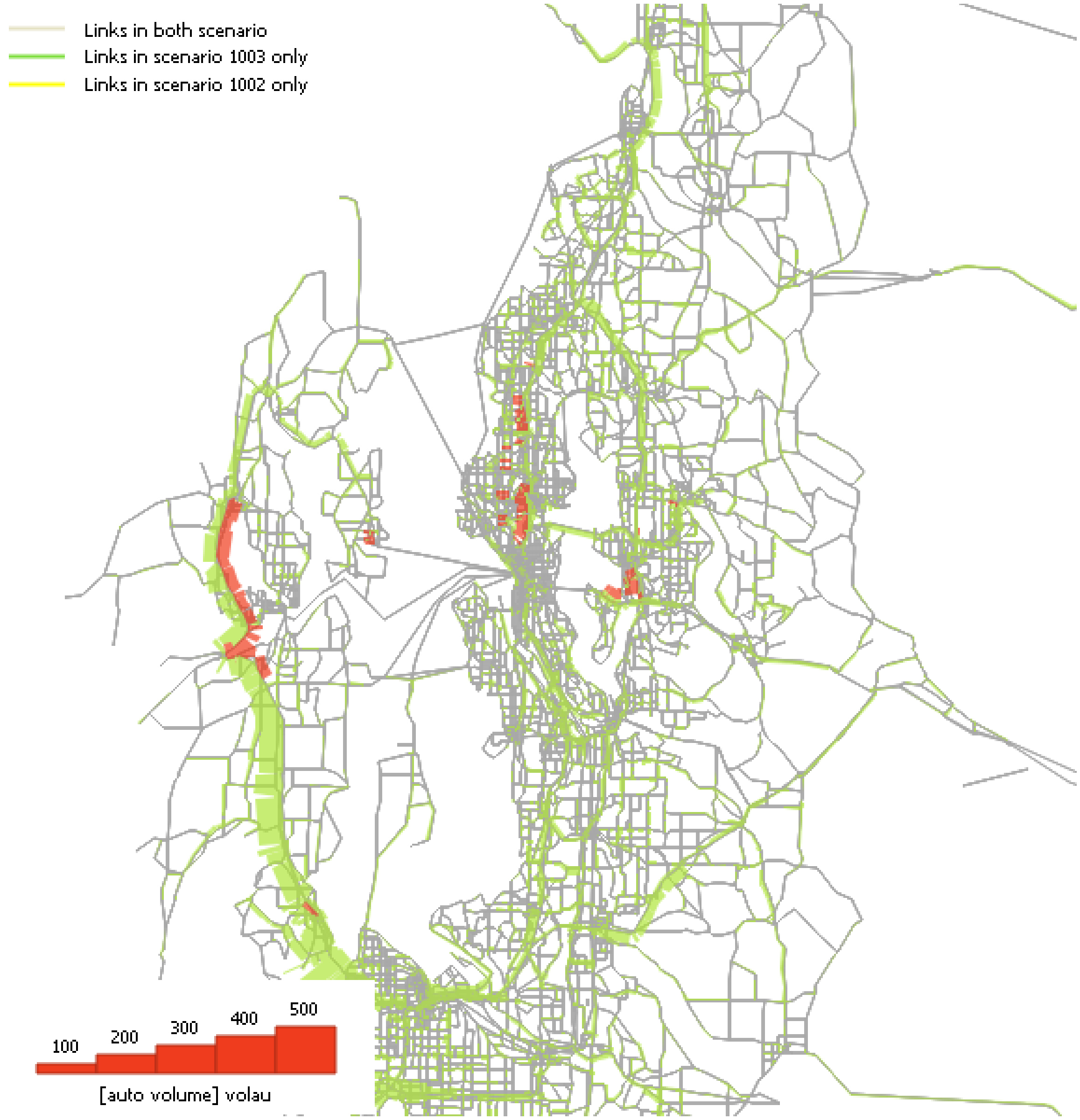

Figure 19. Change in Volume 7 to 8 am with tolls and without
(Green means more volume without tolling)

The next map shows the difference in **speed i**n 7-8 am in the toll and no toll scenario. Green means faster speed in the no toll scenario. Red means slower speed in the no toll scenario.

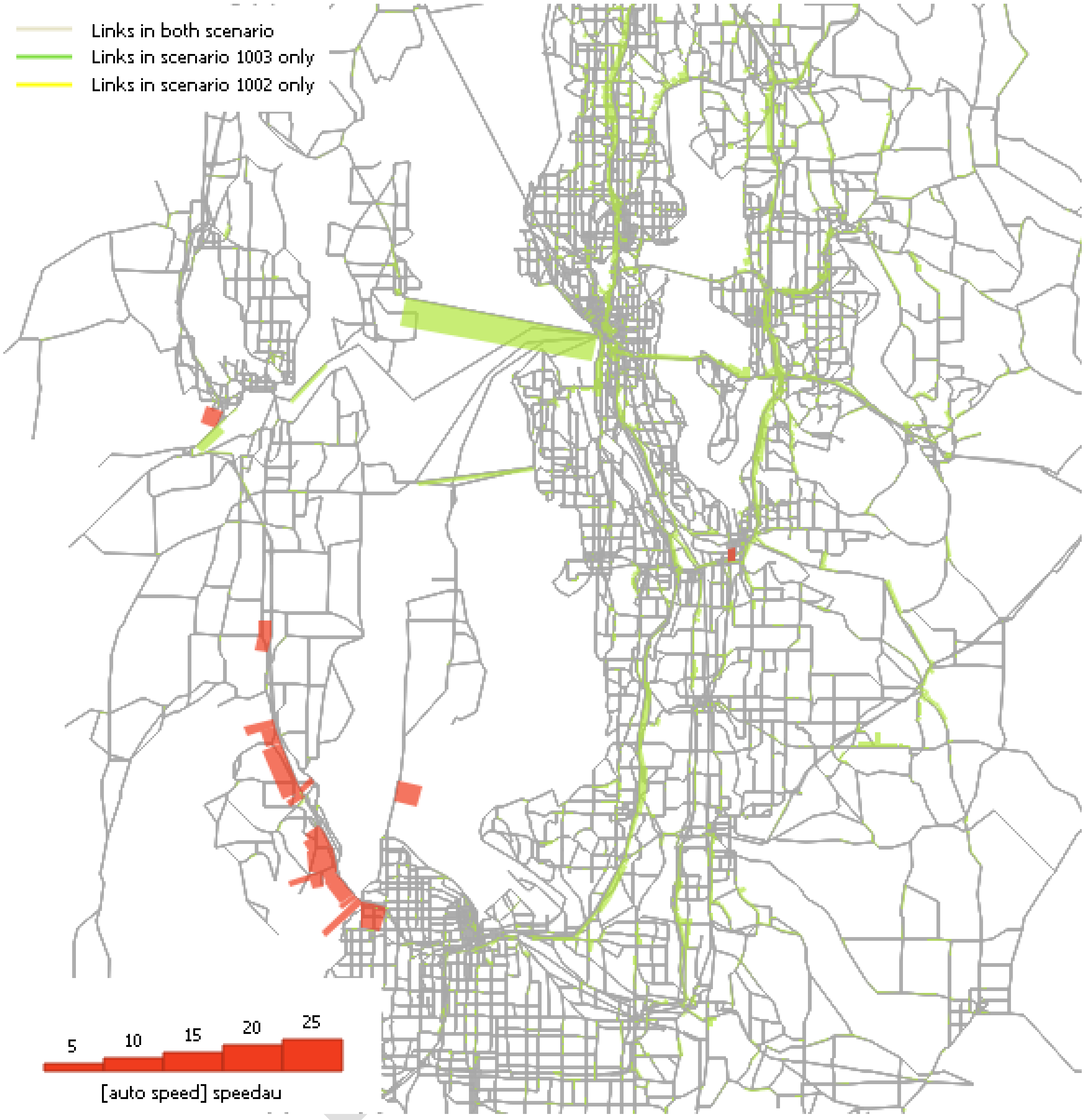

Figure 20. Change in Speeds 7 to 8 am with tolls and without
(Red slower speeds without tolling)

AUTONOMOUS VEHICLES SENSITIVITY TESTS

The modeling team presented a paper at TRB 2015 investigating the potential of using SoundCast to model autonomous vehicles impacts on transportation. Read more here: **http://psrc.github.io/attachments/2014/TRB-2015-Automated-Vehicles-Rev2.pdf**

Table 39. Autonomous Vehicle Scenario Descriptions

Scenario 1	Scenario 2	Scenario 3	Scenario 4
"AVs increase network capacity."	*"Important trips are in AVs"*	*"Everyone who owns a car owns an AV."*	*“"All autos are automated, with all costs of auto use passed onto the user.”*
30% capacity increase on freeways, major arterials	30% capacity increase on freeways, major arterials	30% capacity increase on freeways, major arterials	
	Travel time is perceived at 65% of actual travel time for high value of time household trips (>$24/hr.)	Travel time is perceived at 65% of actual travel time for ***all*** trips	
		50% parking cost reduction	
			Cost per mile is $1.65

The table above describes the scenarios tested. The next table shows the results of these scenarios. With each of these scenarios, it is somewhat difficult to say if the model is correctly sensitive to the input change.

Generally the results show reasonable sensitivities:

- Increases in capacity result in increases in VMT and speed, with longer trip distances
- Transit share increases as the cost of transportation increase.
- Trip lengths are more sensitive to capacity increases than the number of trips.
- Increases in capacity reduce delay.

Table 40. Scenario Results, Base Year 2010, Summaries by Average Travel Day

Measure	Value	Base	1	2	3	4
VMT	Total Daily	78.7 M	81.5 M	82.6 M	94.1 M	50.8 M
	% Change (Versus Base)	**---**	**3.6%**	**5.0%**	**19.6%**	**-35.4%**
VHT	Total Daily	2.82 M	2.72 M	2.76 M	3.31 M	1.67 M
	% Change	**---**	**-3.9%**	**-2.1%**	**17.3%**	**-40.9%**
Trips	Trips/Person	4.1	4.2	4.2	4.3	4.1
Distance (miles)	Average Trip Length	6.9	7	7.2	7.9	5.8
	Work Trips	12.4	12.9	12.9	20	11.5
	School Trips	5.8	5.8	5.8	6.7	4.7
Delay (1000 hours)	Daily Average	846.0	700.0	727.2	996.1	350.2
	Freeways	288.1	201.2	218.3	338.7	56.4
	Arterials	557.9	498.8	508.9	657.5	293.8
Speed (mph)	Daily Average	27.9	30	29.9	28.4	30.4
	Freeways	40	44.7	44.2	40.8	49.2
	Arterials	22.5	23.2	23.1	22.3	24.3
Mode (%)	SOV Share	43.7	43.7	42.7	44.8	28.7
	Transit Share	2.6	2.7	2.7	2.4	6.2
	Walk Share	8.6	8.6	8.4	6.8	13.1

Potential Improvements

The calibration results described here indicate several areas where the model could be improved. The distance distributions on the destination choice models could be over-calibrated so that the model is not sensitive enough to other variables like travel time. It should be considered to remove the distance variables entirely and try to use travel time instead. As was noted before the work location district to district calibration could be improved with a few of the district interchanges.

Estimation of walk-on ferry use needs to be improved. There may be too much urban travel, and not enough suburban and rural. Modeling of Kitsap needs to be improved; there is too much travel overall on Kitsap. The time of day distribution may not be putting enough volume in the peaks or the later day.